VALLES MARINERIS WALLSLOPES: EVIDENCE FOR AMAZONIAN VARIATIONS IN WALLROCK STRENGTH AND OBLIQUE CRUSTAL FABRIC. Daniel Mège and Delphine Gatineau, Laboratoire de Tectonique, UMR 7072, Université Pierre et Marie Curie, Case 129, 4 Place Jussieu, 75252 Paris Cedex 05, France (dmege@lgs.jussieu.fr and delphine.gatineau@wanadoo.fr)

Summary: We have measured angles of gravity slopes that are associated with three morphologic types in SW Valles Marineris: landslides, sapping channels, and a linear trough, Calydon Fossa. Although the three are thought to be gravity-controlled and of the same recent age (Amazonian), significant differences in slope angles are observed. They may reflect variation of rock strength through time, maybe in relation with hydrothermal activity or variations in pore pressure (ice/liquid phase change, desiccation). Many sapping channel slopes are asymmetric. This feature may result from oblique structural fabric in the basement rocks — a possible consequence of uplift-subsidence history during an early Tharsis or pre-Tharsis thermal event?

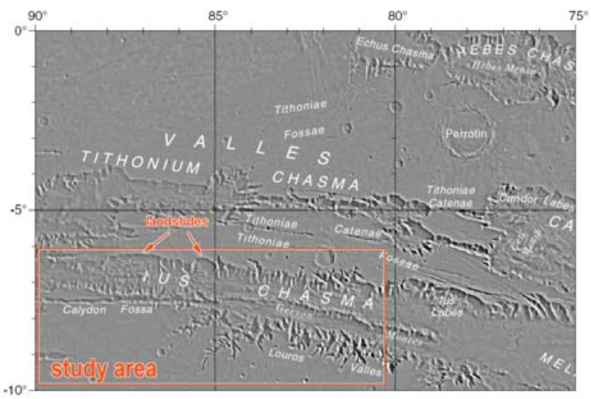

Figure 1. Location of the study area (mosaic USGS/IAU). 1°lat = 55 km.

Introduction: Slope stability angle depends on rock mechanical properties, which in turn reflect both fracture density and orientation anisotropy, and the conditions of fluid flow. The cumulated effect of these parameters can be assessed using Rock Mass Rating (RMR) [1-2]. We have studied stable slopes corresponding to three gravity-controlled morphologic types of Amazonian age in southwestern Valles Marineris [3-4], including landslides (in Ius Chasma), sapping channels (Louros Valles), and Calydon Fossa, a linear trough connected to Ius Chasma whose width is intermediate between catenae and chasmata (Figure 1). Evidence for a major change of morphogenetic conditions in Valles Marineris prior to the development of these morphologic types has already been argued for [4]. Here we investigate the difference in slope angles *between* these morphologies in order to determine whether wallrock strength has further evolved in Amazonian times.

Slope measurements: Topographic profiles across the landslides scars above the debris slope (61), the sapping channels (88), and Calydon Fossa (100) were obtained from MOLA data.

	landslides	sapping channels	Calydon Fossa
Mean slope angle	28.8°	27.6°	25.3°
Maximum slope	33.0°	36.5°	31.8°
Minimum slope	24.7°	19.3°	15.6°
1σ	1.8°	4°	3.2°
Mean slope height	2.9 km	0.7 km	1.2 km

Table 1

Results: The results are summarized on Table 1. Landslide slopes are steeper than the other slopes, and have twice lower standard deviation.

The large standard deviation for the sapping channels is due to channel wall asymmetry. Sapping channel orientation is controlled by a NE-SW and NW-SE gridded fracture network [5] of unraveled origin. In NE-SW, N-S, and E-W oriented channels, 75% to 78% of the NW, W, and N walls have steeper slopes than the opposite walls. There is no significant difference between NE and SW slopes of NW-SE-oriented channels (Figure 2).

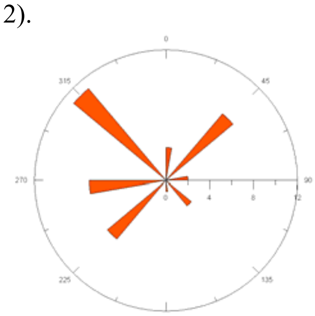

Figure 2. Orientation of the steepest sapping channel slopes in Louros Valles. 78% of the northwestern and western walls, and 75% of the northern walls have steeper slope than the opposite walls.

Figure 3 shows that RMR ranges between 50 and 70 for landslide walls and 20 to 60 for the other walls. The difference in slope between sapping channels and Calydon Fossa is less pronounced given the standard deviation of both slope populations and may not be significant, even though the standard deviation for sapping channel slopes would decrease if the effect of sapping channel asymmetry was removed.

Discussion: *Wallrock strength*. RMR results suggest moderately strong to very weak wallrock. If wallrock is composed of a lava pile [6] in lava flows are numerous, many discontinuity surfaces of various orientations must be intrinsically present [7] and weak wallrock alteration may be sufficient to explain moderate RMR numbers. Lower RMR numbers could correspond to wallrock desiccation [4] or intense alteration of lava products by hydrothermal activity. If the height of the landslide deposits is taken into account, most landslide data points on Figure 3 needs to be displaced upward to RMR values up to 75, corresponding to e.g. rather fresh basalts.

The difference in RMR for the three slope types may result from a change in morphogenetic conditions through time. Wallslopes having the highest RMR would have formed first in rather fresh volcanic rocks. Then, RMR would have decreased possibly with decreasing pore pressure (ice/liquid phase change, desiccation), or with progressive alteration of lava products by fluid flow along joints, lava flow boundaries, and within the pores. The chronology of wallrock morphologic types suggested by this scenario would be (1) landslides, (2) Calydon Fossa and sapping channels.

Alternatively, the difference in RMR for the three slope types may result from local differences in rock composition. Sapping channels and landslides are observed at separate locations along the walls, which is in agreement with local differences in rock composition. However, examination of high resolution MOC images suggests that the Valles Marineris walls are likely to have rather homogeneous properties [7], and several lithologic levels could be followed along the portion of Ius Chasma studied here [8].

Sapping channel asymmetry. Slope angle dependence on wall orientation is unlikely to be due to climatic conditions, as wall asymmetry would probably be observed on other slope profiles as well. A structural origin is favored. Development of sapping channels has been closely guided by basement fracturing [5]. Oblique basement fabric when the sapping channels formed could have induced orientation-dependent slope angles [9]. For instance, sapping above vertical dyke fractures [10] that were later tilted to the present plateau surface slope would explain both slope asymmetry and RMR decrease by hydrothermal flow above the dykes. Tilting could have occurred in response to an early regional thermal event.

References: [1] Hoek, E., and E.T. Brown (1980) *J. Geotech. Eng. Div. Am. Soc. Civ. Eng.*, 106, 1013-1035. [2] Caruso, P.A., and R.A. Schultz (2001) LPSC XXXII, # 1745. [3] Lucchitta, B.K., A.S. McEwen, G.D. Clow, P.E. Geissler, R.B. Singer, R.A. Schultz, and S.W. Squyres (1992), in *Mars*, Univ. Arizona Press, Tucson, 453-492. [4] Peulvast, J.P., D. Mège, J. Chiciak, F. Costard, and P. Masson (2001) *Geomorphology*, 37, 329-352. [5] Kochel, R.C., and A.P. Capar (1982) NASA TM 85127, 295-297. [6] McEwen, A.S., M.C. Malin, M.H., Carr, and W.K. Hartmann (1999) *Nature*, 397, 584-586. [7] Self, S., T. Thordarson, and L. Keszthelyi (1997) in *Large Igneous Provinces: Continental, Oceanic, and Planetary Flood Volcanism*, AGU Geophys. Monograph 100, 381-410. [8] Gatineau, D., and D. Mège (2003) LPSC XXXIV. [9] Hoek, E., P.K. Kaiser, and W.F. Bawden (1997) *Support of Underground Excavations in Hard Rock*, Balkema, 215 p. [10] Ernst, R. E., E. B. Grosfils, and D. Mège (2001) *Ann. Rev. Earth Planet. Sci.*, 29, 489-534.

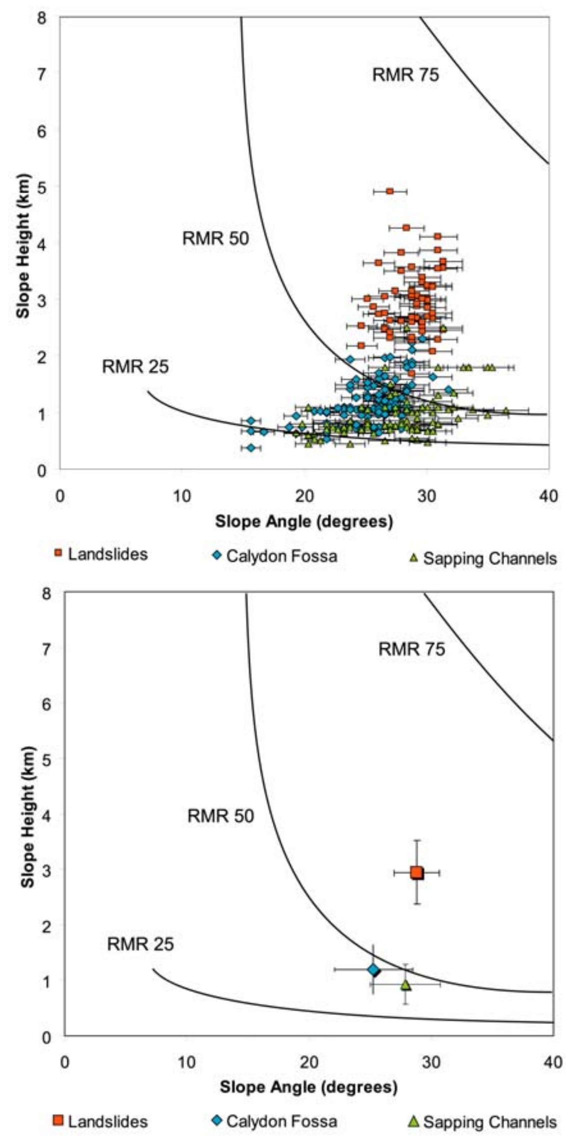

Figure 3. RMR of gravity slopes in the study area. Top: full data set. The error bars are 5% of slope angles. Bottom: mean slopes and standard deviation 1σ (from Table 1). RMR curves from Caruso and Schultz [2]. RMR=100 is for strong intact rock, RMR decrease is proportional to strength loss.